II. CHEMISTRY AND PHYSICS.

RELATIVITY IN SCIENCE.

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All human knowledge is relative. It is beyond the power of man to conceive an isolated fact. We know only by comparison. There is nothing new in this; the most ancient philosophers recognized the force of this truth. Evidently, then, to fully comprehend a fact, we must know it in all its bearings. But again, that is quite impossible, for to know all of any one thing is to comprise a knowledge of the whole universe, so intimately bound up is each fact in every other. As Tennyson has beautifully put it:

> "Flower in the crannied wall,
> I pluck you out of the crannies,
> Hold you there, root and all, in my hand,
> Little flower; but if I could understand
> What you are, root and all, and all in all,
> I should know what God and man is."

Only because of this comparative nature of all knowledge is it possible to have a science; but students of science are frequently led astray in their conclusions. Of course it is beyond any man to grasp a subject in all its bearings, for, as we have seen, that would mean omniscience; but he is the best scientist who can master the most of these relationships.

I purpose in this paper to discuss a few topics in illustration of the interdependence of scientific concepts.

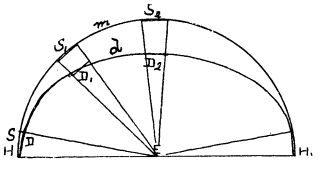
Consider first the simple idea of motion. Think of a wheel of a moving carriage. A chalk-mark on the tire is at rest in reference to that part of the wheel, moves in a circle in reference to the axle, moves in the curve of a cycloid in reference to the horizontal plane; but the path of the chalk-mark is no longer a true cycloid if you remember the earth's surface is spherical instead of plane. Again, referred to the plane of passage, the chalk-mark has a maximum velocity when it is uppermost; that is, the upper half of the wheel is going faster than the lower half; but referred to the wagon axle, the velocity is uniform. The velocity of the carriage may be five miles an hour if we conceive the roadway to be stationary; but if we recall the rotation of the earth on its axis, the velocity at once jumps to a thousand miles per hour. Now think of the motion of the earth about the sun, and, if the time be early morning, to the thousand-mile velocity you must add another nineteen-mile-per-second speed. But we are not yet done, for the sun is hurrying through space toward the constellation of Hercules with a further velocity, guessed by some astronomers to be as much as sixteen miles per second, carrying with him the earth, our carriage, its wheel, and the chalk-mark on the tire. All things considered, what is the path of that chalk-mark?

We speak of the dark Fraunhofer lines in the solar spectrum, which indeed are only dark by comparison with the much more brilliant adjacent field, and which examined independently may be demonstrated to furnish considerable light. Likewise sun-spots are "black" when contrasted with the surrounding portion of the sun's disc; and yet their darkest areas outshine the calcium light.

Frequently the related facts of comparison are quite obscure and seldom consciously recognized. Even when they are sought out they may be missed altogether in some cases, and erroneous conclusions may be stated and find wide acceptance in explanation of certain phenomena.

Consider the case of the apparently increased diameter of the sun or moon when near the horizon over what it is when nearer the zenith. An explanation frequently given for this phenomenon is the unconscious comparison which the observer makes of sun or moon with objects near the horizon. Why does the observer not remember these impressions and give the sun and moon the same value when overhead? Why should there be an "unconscious comparison" at all in the mind of the observer between terrestrial objects at the horizon and the diameter of the sun or moon or planet? This is one of those explanations which gain currency, but which do not explain. It is a false correlation of facts. The true explanation of the familiar phenomenon cited is as follows: To every observer the impression of the contour of the heavens is that of a flattened dome, and not a hemisphere. We all conceive of the heavenly bodies as traversing this dome, on the surface of which we naturally think of them as located. This is a childhood conception of the heavens, and all subsequent education and knowledge of the varying immense distances of the heavenly bodies can do practically nothing to alter these natural impressions. The dome appears flattened because we conceive of the distance to the blue in the direction of the horizon as greater than that overhead.

In the illustration herewith given, let HH_1 represent the horizon, E the position of the observer, HMH_1 a semicircle, and HdH_1 the apparently flattened dome of the heavens. The angle of vision at E, subtended by the moon's diameter, is slightly greater when the moon is in the zenith than when it is near the horizon. So the moon should actually appear larger when overhead than when rising; for when it is directly overhead we are nearer to it by the distance equal to the earth's radius. But the difference in visual angle due to this nearer approach is so slight as to pass unnoticed, unless we take special pains to detect it, as may be done by looking at the moon through a roll of paper so adjusted as to just take in its disc when at the horizon. When at the zenith the whole moon will no longer be visible through the paper roll, proving it to be actually nearer, though to the eye apparently smaller. Neglecting this small difference, the visual angle is practically the same wherever the moon may be, and therefore that body should always appear of the same dimensions; and it would so appear did we but refer its position to the surface of a sphere and therefore always at the same distance, instead of to the surface of a flattened dome, and consequently at varying distances. In the illustration, an object referred to S, S_1, or S_2 will not change in apparent dimensions, but referred successively to D, D_1, D_2, it will apparently grow smaller until directly overhead, and thereafter will seem to grow larger until again in the horizon at H_1. Thus we see that "objects near the horizon, such as trees, buildings, etc.," having nothing to do with the apparent size of the moon, sun, or other heavenly bodies. The stretch of the earth's surface far out toward the horizon, beyond which we must still think of the blue vault as located, gives us an impression of greater distance in that direction to the blue than directly overhead. Besides, the greater quantity of light that



comes from the sky overhead than from that low down would also tend to an impression of greater nearness for the former.

Scientific explanation is nothing more than the bringing together the more closely related facts. When we seek such an explanation we endeavor to discover relationships between the facts. Consider another illustration:

It is frequently asked why our visual impressions of objects about us are not inverted, inasmuch as the image on the retina of the eye can clearly be demonstrated to be inverted. Inverted with respect to what? is our first question. The reply may be: Inverted with respect to the object itself. The antonym to the term "inverted" is "erect," which means the normal position of the object with reference to the horizon and to other associated objects. In the picture formed on the retina of the eye these external relationships as they appear are not disturbed, and therefore how could the object contemplated be considered as inverted? To the acrobat standing on his head the world does not appear upside down, for he recognizes that it is he who is inverted for the time being, while all other objects hold a normal position with reference to each other.

It was only by carefully tracing the relativity of phenomena that Count Rumford and William Robert Grove and Julius Robert Mayer were enabled to arrive at that grandest of scientific generalizations, that all energy is correlated and is forever conserved. They recognized that all energy is one and the same, however variously manifested. Energy is the capacity which moving bodies have, by virtue of their mass and motion, of imparting movement to other bodies. Hence they recognized but one kind of energy, that which afterward received the name of "kinetic" energy.

All energy is kinetic, for displacement of a body through space can be accomplished only by one moving body imparting its motion to another, whether that motion be of a mass, and so known as mechanical; or of molecules, and so known as heat; or of atoms, and therefore known as chemism; or of ether vibrations, and known as light, electricity, magnetism, or gravity. The physical concept "energy" must ever hold motion as an essential property—motion of mass, of molecules, atoms, or ether particles. I am aware that an expression known as "potential energy" has crept into physical discussions and has been copied from one text-book to another now for a generation or two, and seems likely to be continued by compilers of texts on natural philosophy for some generations to come. As I endeavored to point out before this Academy six years ago, at the Ottawa meeting, I still maintain that there is no such thing as potential energy, except as we may in a loose way regard all energy as potential in the sense that it is possible, as heat, light, electricity, or gravity, to be intertransformed. As ordinarily presented in texts on physics, the concept "potential energy" is a false correlation, and the result of surprisingly slovenly thought.

To illustrate: A lad holds a ball in hand which he purposes to toss in air. Were I to assert that that ball possessed energy of any kind in relation to the conditions presented—those of the boy's hand and the plane of its position as the plane of reference, you would rightly pronounce the statement absurd. Please, then, where is the difference of related conditions after the ball has been tossed upward and rests for an instant poised in mid-air in the hand of gravity? And yet, under the latter conditions, we are told that the ball possesses a peculiar energy—"potential energy"—the result of the conversion of the kinetic energy it possessed at the beginning of its ascent. Now what is the true relation of the facts, which relation has been overlooked in presenting the false deductions called "potential energy"? They are as follows: The ball in rising is doing work against the force of gravity; that is, it is accomplishing ether dis-

placement, for gravity must reside in the ether. But whenever work is done, energy is transformed or transferred. The energy of mass motion in the rising ball is gradually transformed to energy of ether motion as gravity, *and is not in any sense whatever stored in the ball.* As gravity energy, it exists in the ether and may at once be reconverted into energy of mass motion to return the ball to earth; or if the ball find a support at its higher elevation, that energy will persist as gravity energy. The mere possibility of the ball falling to earth again does not give it any quality of energy whatever, any more than the first possibility of its being tossed into the air made it a possessor of energy. But the nature of gravity is so little understood that the foregoing reasoning may be received with some hesitancy. Let us therefore consider another illustration commonly employed in the text-books.

The heat of fuel is frequently spoken of as "stored energy" derived from the sun at the time the plants were growing. I once heard an intelligent lady state that the iridescence of anthracite coal was fossil sunshine. Let us consider the relationship of the facts as we best know them, and we will find no room for the subterfuge of "potential energy." The energy of carbon atoms vibrating as such, and of oxygen atoms vibrating as such, is greater than that of these elements vibrating together as carbon dioxide. Therefore, in order to maintain the vibrations of carbon and oxygen separately, some energy must be taken up as transformed from some other source, it matters not from what source derived. Usually that source is sunshine. The sunshine falling upon the green chloroplasts of living leaves enables them to separate the absorbed carbon dioxide into its constituents of carbon and oxygen, because the additional necessary energy is thus furnished. But that additional energy utilized is now no longer energy of sunlight, but it is energy of chemism; and in no proper sense can it be looked upon as stored sunlight any more than the resulting products of carbon and oxygen may be regarded as stored carbon dioxide, or the lumber in a lumber-yard as stored houses. In after time, when the wood or coal is again burned, that is, when the carbon again unites with ogygen, the surplus of chemical energy necessary to the carbon atoms and the oxygen atoms as such, over that which exists in their constitution as carbon dioxide, is transformed mostly to heat, some of it to light or electricity possibly, and is but another transformation. A conspicuous absurdity of the text-books is to speak of the energy of the sunshine as all stored in the carbon or carbon compounds formed in plants from the carbon dioxide taken from the air. As we have seen, the oxygen, separated, plays as important a part in the processes as the carbon. Then why not say the solar energy was stored in the oxygen as well as in the carbon separated? When carbon and oxygen unite in combustion, why is it not said that the oxygen furnished its quota of stored solar energy?

Let us bear closely in mind the relationship of all the phenomena concerned, and "potential energy" will become an obsolete term, "stored energy" will drop from the vocabulary of physical science, and we will read there only and ever in their stead "transformed energy."